



Materials Engineering Branch, Code 622



Cadmium Replacements for High Strength Steel Fasteners

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NSWCCD-SSES

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Background

- Cadmium commonly used on steel fasteners
 - easy deposition, corrosion resistance, low CoF, solderable
 - probable human carcinogen
 - can cause anemia, emphysema, and bone, kidney & liver diseases
- Chromium (VI) commonly used as a post treatment on Cd
 - enhances corrosion resistance of cadmium
 - human carcinogen
 - can cause ulcers and lung cancer
- Cd & Cr impact on life cycle costs
 - satisfactory performance
 - operator exposure, environmental emissions
 - waste related processing

Objectives

- Eliminate the use of electroplated Cadmium in high strength steel fastener applications
- Reduce and/or eliminate the use of Chromium in high strength steel fastener applications



JTP Tests

- General Properties
 - appearance (visual inspection)
 - coating thickness (ASTM B487)
 - max temperature (24 hr exposure-visual inspection)
- Corrosion
 - SO₂ salt fog w/ & w/o defect (500 hr ASTM G85-A4) [fastener & panel]
 - cyclic wet/dry corrosion w/ & w/o scribe (160 cy GM9540P) [fstnr & pnl]
 - galvanic bi-metallic (GM9540P)
 - fluid w/ & w/o scribe [coupon]
- Adhesion
 - water boil (modified ASTM D3359 - A)
 - bend (ASTM B571) [pnl]
 - paint (dry & water immersion) (ASTM D3359 - B) [pnl]



JTP Tests (continued)

- Assembly
 - breakaway torque w/ & w/o corr expos (ASTM G85-A4 & GM9540P)
 - fastener COF (1/3 & 2/3 YS, 3 cycles)
 - torque tension (30, 40, 50, 60, 70, 80, 90% YS, 5 cycles)
- Longevity
 - fatigue (NASM 1312-11) @ 70 ± 30 ksi mean stress w/ & w/o corr expos
 - stress durability (ISO 15330) @ 96 hr w/ & w/o corr expos
 - slow strain rate (ASTM F606) @ 0.001"/min w/ & w/o corr expos
 - strippability (MIL-S-5002D) [fstnr & pnl]
 - bend test after coating reapplication
 - stress durability (ISO 15330) @ 96 hr before & after ctg reapplic



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| Test # | Test Name | Other Samples | Coated 4"x6" plate | Uncoated Fastener Systems | Coated Fastener Systems | GM 9540 Fastener Systems | ASTM G85 A4 Fastener Systems |
|----------------|-----------------------------------|---------------|-----------------------|------------------------------|----------------------------|-----------------------------|------------------------------------|
| 3.1.1 | Appearance | - | - | - | 10 | - | - |
| 3.1.2 | Coating Thickness | - | - | - | 3 | - | - |
| 3.1.3 | Maximum Temp. | - | - | - | 3 | - | - |
| 3.2.1 3.2.3 | Unscribed Corrosion Exposure | - | 6 | - | 20 | - | - |
| 3.2.2 3.2.4 | Scribed Corrosion Exposure | - | 6 | - | 20 | - | - |
| 3.2.5 | Galvanic Bi-Metallic Corrosion | 45 washers | - | - | - | - | - |
| 3.2.6 | Fluid Exposure | 120 coupons | - | - | - | - | - |
| 3.3.1 | Water Boil | - | - | - | 3 | - | - |
| 3.3.2 | Bend Adhesion | - | 3 | - | - | - | - |
| 3.3.3 | Paint Adhesion | - | 9 | - | - | - | - |
| 3.3.4 | Water Immersion Paint Adhesion | - | 27 | - | - | - | - |
| 3.4.1 | Breakaway Torque | - | - | - | 10 | 10 | 10 |
| 3.4.2 3.4.3 | COF Torque Tension | - | - | - | 10** 10** | - | - |
| 3.5.1 | Fatigue | - | - | 5 | 5 | 5 | 5 |
| 3.5.2 | Stress Durability | - | - | 10 | 10 | 10 | 10 |
| 3.5.3 | Slow Strain Rate | - | - | 10 | 10 | 10 | 10 |
| 3.5.4 | Strippability | - | - | - | 10 | - | - |



JTP Status

- Draft issued 17 Mar 2004 and sent to 39 technical stakeholders/contributors
- 291 comments received and adjudicated
 - Eric Brooman (AFRL)
 - Joe Osborne (Boeing)
 - Harry Archer (NSWCIHD)
 - Ralph Adler (ARL)
 - Tim Tenopir (PHD NSWC)
 - Michael Kane (AMCOM)
 - Patrick Doyle (NAWCADLKE)
- Selected Issues
 - Zn vs Cad as control
 - Grade 8 (150 ksi) vs 180 ksi or 220 ksi fasteners
 - Use of dry film lubricants
 - Mandatory and service specific tests/requirements



Preliminary Field Demo

- Fastener: 1.25" (length), 3/8" - 16 UNC grade 8, hex head cap screw
- Nuts installed/removed 5 times
- Fasteners torqued to 90% YS on 4142 plate
- 1 hr dwell, torque reapplication
- Installed on MTRV (Lejeune, NC; Kaneohe Bay, HI; Okinawa, Japan)



Candidate Coating Systems

- Zn with Cr post treatment
- Zn with proprietary non Cr treatment
 - Cd originally planned
- Zn/Al Flake in inorganic binder with friction control TC
- Zn/Al Flake with Cr in inorganic binder with friction control TC
- ZnNi per SAE AMS2417E
- ZnNi with silicate surface conversion and black UV TC



KB #205



OK #201



KB #100



CL#118





Torque Data

| | DFT (mils) | COF | Initial Torque (ft-lb) | Unexpos BA Torque (ft-lb) | 1 Yr Fld Expos BA Torque (ft-lb) | BA Torque % Change |
|--------------------------|-----------------------|-----------------|---------------------------------------|--|---|---------------------------------------|
| Zn w/Cr | ~0.3 | 0.11 | 46 | 38 | 60 | 159 |
| Zn w/NC | ~0.3 | >0.08 | 50 | 41 | 47 | 113 |
| Zn/Al | 0.4-0.6 | 0.11 | 46 | 21 | 28 | 137 |
| Zn/Al/Cr | 0.2-0.5 | 0.11 | 46 | 22 | 28 | 125 |
| ZnNi | 0.3-0.5 | 0.08 | 70 | 62 | 58 | 94 |
| Modified ZnNi | 0.25 | 0.13 | 53 | 32 | 30 | 96 |



Slow Strain Rate Data

| | DFT (mils) | Initial Unexposed UTS (ksi) | 1 Yr Field Exposure UTS (ksi) | UTS % Change |
|----------|---------------|--------------------------------------|--|-----------------|
| Zn w/Cr | ~0.3 | 166 | 164 | 98.4 |
| Zn w/NC | ~0.3 | 164 | 162 | 98.9 |
| Zn/Al | 0.4-0.6 | 170 | 169 | 99.3 |
| Zn/Al/Cr | 0.2-0.5 | 166 | 165 | 99.6 |
| ZnNi | 0.3-0.5 | 170 | 167 | 98.6 |
| Mod ZnNi | 0.25 | 170 | 161 | 94.6 |

Note: thread stress area based on ASTM F606, $A_s = 0.7854 [D - 0.9743/n]^2$



Conclusions

- Draft JTP issued
- Draft JTP reviewed by technical stakeholders
- Draft JTP comments adjudicated
- Field exposure test on operational USMC vehicles initiated
- 1 yr field exposure samples collected (analysis ongoing)
- Based on data collected to date:
 - ZnNi and modified ZnNi coatings appear to maintain lubricity
 - Zn w/NC and Zn/Al coatings are displaying the most surface corrosion
 - Hydrogen embrittlement has not been detected wrt coating application nor during field service
- Further JTP coordination on hold until endorsement by DOD